'Green' Hybrid Composites using Modified Soy Protein Resin with Kenaf Fibers and Fibrillated Bamboo

Anil N. Netravali[1]*, and Yuzo Yamamoto[2]

[1]Department of Fiber Science and Apparel Design Cornell University, Ithaca, NY, 14853, USA
[2]Bosch Corporation, Abashiri-gun, Hokkaido 099-2371, Japan
*ann2@cornell.edu (Corresponding Author)

1. Introduction

Fiber reinforced composites are routinely used in place of metals because of their high strength-to-weight ratio. Most composites that have been commercialized to date are made using fibers and resins that are petroleum based and non-degradable. Since composites use two dissimilar materials they cannot be easily recycled or reused. Over 90% of them end up in landfills making that land unusable for decades, if not centuries. Environmentally smart solutions already exist to make *green composites* that use plant based fibers and resins that are annually renewable and fully sustainable [1].

These green composites have been made using natural fibers in various forms, e.g., fibers, yarns, fabrics or nonwoven mats and a variety of resins. Because of their moderate mechanical properties they are useful for a variety of applications including packaging, product casings, panels for housing and transportation etc. In many applications the toughness is an important factor. This paper describes green composites made using kenaf fiber mats and hybridized with fibrillated bamboo to improve the mechanical properties. The resin used in these green composites was based on soy protein.

2. Experimental

Soy protein isolate (SPI) powder, PRO-FAM® 974, was obtained from ADM Co., Decatur, IL. Glycerol and sodium hydroxide (NaOH) were purchased from Fisher Scientific, Pittsburgh, PA. Gellan was obtained from Sigma-Aldrich Co., St. Louis, MO. The nonwoven kenaf mat was supplied by Flexform Tech. Co., Elkhart, IN, and fibrillated bamboo fiber (FBF) in the form of water based slurry was provided by Doshisha University, Kyoto, Japan.

SPI resin sheets were prepared using a casting method. To make the sheets desired amount of SPI powder and glycerol were weighed separately and mixed with 12 times (by wt of SPI) distilled water in a beaker. The mixture was stirred in water bath at 75°C for 40 min. The NaOH was added to obtain required pH values while stirring. This pre-cured resin was poured on to a Teflon®-coated glass plate and dried at 50°C for 24 hr in an oven. The dried sheet was then hot pressed (cured) on a Carver Hydraulic press at 120°C for 20 min at 2.1 MPa pressure.

Soy resin was also modified to obtain better mechanical properties using gellan. For this the same process was used except that the gellan was dissolved separately in water and this mixture was added to SPI resin while pre-curing. The same drying and curing process was used.

Nonwoven kenaf mat based *green* composites were fabricated using both gellan modified SPI (SPIG) and SPI resins by compression molding. Kenaf fiber mats were cut to desired size, impregnated with the resin and dried at 50°C for 24 hr (prepregs) in an oven. Final curing of the composites was carried out by hot pressing 4 prepregs in 4 steps from 80°C to 120°C with increasing pressure. The cured laminated composite was weighed to calculate the fiber content. The composites were conditioned prior to characterizing their properties.

Green hybrid composites were prepared by incorporating FBF sheets in between the kenaf mat prepregs using SPIG resin as shown in Figure 1. The proportion of kenaf fiber:FBF:SPIG resin was 4:1:5 by wt. To obtain the FBF sheets, the FBF dispersion was spread on to a filter paper set up on a vacuum steel plate with holes. After removing water the FBF sheets were simply peeled off from the filter paper and dried.

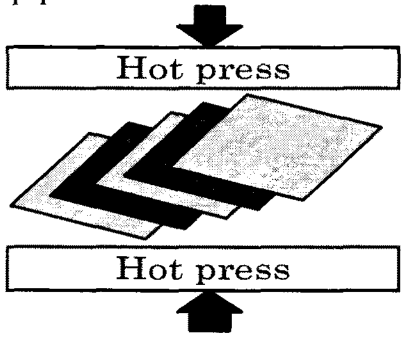

Figure 1. Kenaf mat and FBF sheet layering arrangement for hybrid composites. The dark sheets are FBF.

The composite mechanical, flexural and impact properties were characterized. The kenaf fiber interfacial shear strength (IFSS) with the resin was characterized using microbead tests [2].

3. Results and discussion

The tensile properties of the SPI resin showed significant increases when gellan was added. The tensile strength increased from about 25 MPa to 59 MPa with 40% addition of gellan and Young's modulus increased from about 844 MPa to 1787 MPa. This was due to the formation of an interpenetrating network-like (IPN-like) structure that was also heavily hydrogen bonded.

The kenaf fiber-SPI resin IFSS increased with gellan from 3 MPa for SPI to over 4.5 MPa for SPIG containing 40% gellan. This can increase composite strength and modulus.

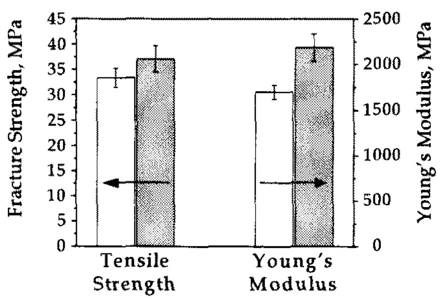

Figure 2. Comparison of tensile properties of kenaf mat composites with hybrid (kenaf + FBF) composites (shaded column).

It is clear from Figure 2 that both tensile strength and Young's modulus increase after hybridization. This is due to higher strength of the FBF sheet which is derived from the strength and stiffness of bamboo fiber itself.

It is evident from Figure 3 that while the flexural strength decreased slightly the modulus increased. The decrease in the strength is attributed to the decrease in the flexural strain as a result of the FBF sheet stiffness.

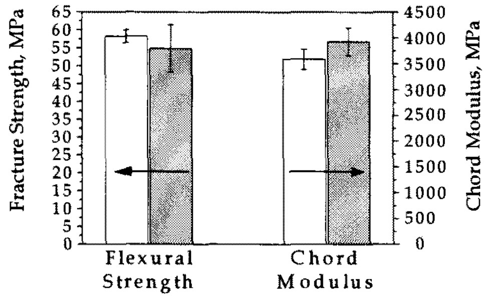

Figure 3. Comparison of flexural properties of kenaf mat composites with hybrid (kenaf + FBF) composites (shaded column).

It is clear from Figure 4 that the impact strength increased significantly after adding FBF sheets which are much stronger. These results suggest that it is possible to improve the mechanical properties by addition of FBF.

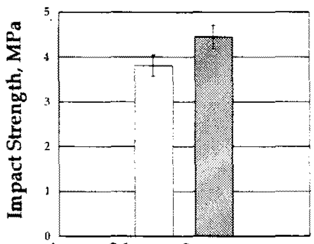

Figure 4. Comparison of impact properties of kenaf mat composites with hybrid (kenaf + FBF) composites (shaded column).

4. Conclusions

The tensile properties as well as the IFSS of the SPI based resin with kenaf fibers increased after adding gellan to SPI. Green hybrid composites can be fabricated with improved mechanical properties. It should be easily possible to manipulate the properties of the composites using a variety of fibers and addition of stronger fibers.

References

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